DATA ON BENSON ROAD

Contract Price.....$5,983
Length.....2 miles
Average Cost Per Mile.....$2,992
Average Haul.....26 miles
Fill..... 2,000 cubic yards
Cut.....11,000 cubic yards

The average cost of the three projects was approximately $3,500 per mile.

DESIGN AND CONSTRUCTION OF A CONCRETE ARCH BRIDGE

By George F. Gault, Wayne County Surveyor

The Whitewater River flows through Richmond from north to south. At the north edge of the city the banks are of ordinary height, but as you proceed down stream the valley becomes much deeper. At a point about six blocks north of Main Street (which is U. S. Road 40 or the Old National Road), the Pennsylvania Railroad has a steel deck truss over the river valley. This bridge is about 600 feet long and about 70 feet above the river. About four blocks north of Main Street, a steel arch highway bridge was constructed about forty years ago. This bridge is of approximately the same length and height as the railroad bridge. At Main Street a reinforced concrete arch bridge of the open spandrel type was built in 1917-18. This bridge is 640 feet long and about 70 feet above the water. Prior to the construction of the South "G" Street bridge there was no bridge over the river valley south of Main Street for a distance of one and one-half miles.

As the C. & O. Railroad is located on the east bank of the river valley, the lands on this side of the valley, about ¾ mile south of Main Street, were developed for industrial purposes and the lands on the west side for residential purposes. Several of the industrial plants grew rapidly and a need was felt for some means of crossing the valley at this point in order that the workmen who were living on the west side of the river and within a few rods of their work might reach their work without going up to cross Main Street bridge and then back, a distance of about one and one-half miles. A further need was felt because of the fact that it had become necessary to limit the loads passing over the old steel bridge. This left only one bridge at Richmond of sufficient strength to carry modern loads, and this, in addition to the Main Street traffic, had also to carry all the traffic of the National Road.

After much discussion, it was decided to locate the new bridge at South "G" Street, and in 1917 the necessary land

was purchased and the street opened across the river valley by the city of Richmond. The plans and specifications for a new bridge were prepared and the work advertised for bids. No bids under the engineer's estimate were received and the work was dropped until the bonds for Main Street Bridge mentioned above had been retired. The last of these bonds was paid in 1927, and in 1928 an appropriation of $5,000 was made by the county council to cover the cost of preparing plans and estimates. A careful survey was made and the work on the plans and estimates was started. A petition was filed with the board of county commissioners asking that the plans, estimates, and specifications be approved by the Indiana State Highway Commission and that it furnish inspection for the work. In compliance with this petition, a formal request for recommendations and assistance in preparing the plans and specifications and for inspection during construction was filed with the Highway Commission on November 8, 1928. Tentative designs for a reinforced concrete arch bridge and for a steel deck truss bridge with concrete abutments and floor were submitted to the board of commissioners. A public meeting was held, and after arguments had been presented by representatives of the Portland Cement Association and the American Steel Institute, it was found that the majority of those present were in favor of the concrete bridge. Complete detail plans and specifications were then prepared for the structure.

DESIGN

Since test holes and borings had shown that the sides of the river valley were of limestone rock formation and that the bottom of the valley was gravel to a greater depth than it was practical to dig the foundations, and on account of the height necessary to get a level bridge across the valley, it was deemed most economical to make as few spans as possible and thus reduce the number of foundations on gravel to a minimum. It was found that three spans of 160 feet each would reach from rock to rock and give only two piers on gravel. These main arches were identical and the springing line was in the same plane. To complete the bridge, an arch of 48-foot span, but with the springing line much higher, was added at each end, and four spans of trestle approach were placed back of the small arch at the west end and two spans of trestle approach at the east end. This made the entire length of the bridge about 725 feet. (Figs. 1 and 2.)

By an empirical formula, the thickness of the arch ring was assumed at the crown and the thickness at the haunch and quarter points determined from the assumed crown thickness. A tentative design was then completed and the dead loads calculated.

Fig. 1. "G" Street Bridge from down stream side giving some impression of the size of the structure.

By the use of an equilibrium polygon and mathematical analysis, it was found that a three-centered arch with a rise of 67 feet would give the proper strength and present a pleasing appearance for the main arches. By the same means the smaller arches were also designed and detailed. The dead and live loads were then applied and the details completed for the entire structure. In order to keep the dead load as small as possible, it was found necessary to make the pier shafts hollow above the haunches of the main arches. It was found that two arch ribs each 12 feet in width and 20 feet center to center would be sufficient.

On account of the gravel foundation for the two piers in the river bottom, it was thought best to support the piers on piling. All the other foundations were on rock. The length of the piling was fixed at 24 feet, and allowing 25 tons bearing on each pile, it was found that 286 piles would be required for one pier and 308 for the other. The piles were spaced about 30 inches center to center each way. The supporting strength of the piling was made large enough to carry the entire load on the piers. The soil pressure at the other piers and abutments varied from 3.6 tons to 6 tons per square foot. The grade of the floor slab was fixed at 0.5 per cent. descending toward the west, and the springing lines of the arches were placed on the same grade. A depression 9 feet in width and approximately 17 inches in depth was left in the center of the floor slab so that a street railway track could be laid across the bridge with the tops of the rails level with the floor slab.

After this design had been completed and approved by the State Highway Commission and the bonds to cover the

Fig. 2. A close up view of "G" Street Bridge showing more in detail the two-rib arch, open spandrel construction.

cost of the construction had been advertised for sale, a remonstrance was filed against the sale of the bonds on the grounds that the cost was excessive. Our plans provided for a roadway 42 feet in width with 8-foot sidewalks on either side. After a hearing conducted by the State Tax Board, we were ordered to reduce the width of the roadway to 32 feet and the width of the sidewalks to 6 feet, and to then advertise for bids and submit them to the Tax Board. The plans were revised accordingly and bids were advertised to be received in December, 1930. Nineteen bids were received ranging from $198,845 to $269,800. One bid on an alternate plan was received, but as it was not the lowest bid the question as to its legality did not arise.

The I. E. Smith Construction Company of Richmond submitted the low bid and was awarded the work by the board of commissioners, which action was approved by the State Tax Board. Pending sale of the bonds, only preliminary work was done during January and February, 1931. Active work was started about March 20 and the structure was completed and accepted on June 18, 1932. The time for completion had been set for September 1, 1932, but on account of the favorable weather during the winter of 1931-32, it was completed two and one-half months ahead of time.

MATERIALS

All materials used were obtained locally when possible. The necessary foundation and construction piling were cut in Wayne and adjoining counties and hauled by truck to the bridge, with the exception of two car loads.

The sand and gravel were obtained from a washing and grading plant located about one block south of the site of the

bridge on the east bank of the river valley. These materials were hauled by truck from the plant to stock piles where they could be reached by a clam shell and placed in storage bins, whence they ran by gravity into measuring boxes and again by gravity into the mixer.

Steel was furnished by the Joslyn Manufacturing and Supply Company of Fort Wayne, Indiana.

As the bridge is located entirely within the corporate limits of the city of Richmond, it was possible to obtain an unlimited supply of clean water at all times. Electric current was also obtained from the Richmond City Municipal Light and Power Plant.

The specifications for materials were those of the Indiana State Highway Commission, and tests of material were made by the State Testing Department.

PLANT LAY-OUT

By reason of the topography of the site and the location of the sand and gravel washing plant, the contractor decided to mix the greater part of the concrete on the east bank of the river valley. Fortunately enough, right of way had been secured to permit the construction of storage bins for the sand and gravel and for placing the mixer, a cement shed, and derrick for charging storage bins so that they could remain in position until the work was completed. Piling was then driven and an industrial track built across the river at an elevation just above the springing lines of the main arches. A hopper of one-yard capacity was placed at the east end of this track at an elevation that allowed the concrete to flow directly from the hopper into a small dump car on the industrial track. This dump car was then hauled by a gasoline locomotive and the concrete dumped into chutes for the lower parts of the work, or into a bucket in the 120-foot tower which was used for the higher parts. This tower was powered by an electric hoist, and was equipped with a flexible quick-shift hopper and spouting which could be raised or lowered as necessary.

The cement house was so located that the cement could be delivered on a level to the measuring boxes with very little effort. Measuring boxes for sand, gravel, and cement were located so that all materials could be dumped at the same time into the mixer skip. The mixer was of one-half yard capacity and was operated by an electric motor. As the capacity of the remaining equipment was one yard, the mixer emptied into spouting which carried the concrete about 60 feet to the hopper over the industrial track as mentioned above. The concrete was then emptied from this hopper to the small dump car and hauled and dumped either into chutes, leading directly to the forms, or into the bucket on the tower, where it was elevated and delivered to the chutes at a higher level.

A small plant was operated on the west bank of the river valley for those parts of the structure above the industrial track and beyond the reach of the spouting from the tower. The method of mixing and handling was practically the same as at the east end, but the concrete was delivered to the forms by hand-operated dump carts.

The labor operations on mixing and delivering the concrete from the main plant on the east end were as follows:

One man operating electric hoist with clam-shell charging bins.
One man at the measuring boxes for sand and gravel.
Two men to bring up and dump cement.
One man operating mixer.
One man operating gasoline locomotive.
One man on the electric hoist for tower.
One man at the hopper at the top of the tower to regulate the flow of concrete into the forms.

As the capacity of this outfit was from 150 to 200 cubic yards per day, the cost of mixing and delivering the concrete to the forms was only about 20 cents per yard.

It will be noted that electricity was the power used for operating the greater part of the equipment. Two 52 H. P., one 50 H. P., one 30 H. P., one 20 H. P., one 10 H. P., and two 5 H. P. motors were in use for 15 months. The cost of current was $550.05. These motors were not in constant use, but were available when needed.

Gasoline was used in two cranes, in a gasoline locomotive for distributing concrete and for part of the pumping in unwatering the foundations.

Steam was used only for operating the steam hammer used in driving the piling and for heating the aggregates during the winter months.

The excavation, pile driving, setting up and taking down of the forms, and the placing of the reinforcing steel was mainly done with a "Lima 101" crane, weighing 75,000 pounds, with a boom length of 50 feet, a capacity of 26,400 pounds at a 12-foot radius and 4,800 pounds at a 50-foot radius. The boom length was increased to 70 feet for the higher parts of the work.

FALSEWORK

A design for the centering of the main and approach arches was submitted by the contractor and approved by the Indiana State Highway Commission and the county engineer. This consisted of piling bents of 9 piles each which were cut off and capped so that the top of the cap was about 16 inches lower than the haunch of the main arches. Above this, frame bents were used, the posts and caps being of 10 by 10-inch timbers and 2½ by 8-inch lumber being used for diagonal bracing in both directions. These frame bents were assem-

bled on the ground and hoisted into position by the crane mentioned above. For the purpose of determining the exact height of these bents, one half of the two sizes of arch were laid out full size on level ground near the bridge. It was then possible to get the desired height of bent from this layout at any point. Thirteen lines of 4 by 12-inch joists were then laid over the top of these bents, the bents being so placed that the joists were 14 feet in length. These joists were shaped to conform to the intrados of the arch and 2-inch lagging laid and surfaced so as to give as good a line as possible to the concrete. Five sills of 12 by 12-inch timbers were laid longitudinally under the sills of the frame bents and 10 by 10-inch timbers placed crossways under these sills directly over the piling bents. By means of hardwood wedges driven between the cross timbers and the caps on the piling bents, the entire centering was then raised about 6 inches to its proper position. After the concrete for one rib had been poured and allowed to set, these hardwood wedges were driven out and 3-inch wooden rollers placed in the space where the wedges had been. This allowed the centering to clear the concrete at the top and by means of 7 hand-operated fence stretchers, the entire centering above the piling was shifted into position for the arch rib directly opposite, wedged up to its proper position, and the concrete poured for this rib.

About 1,000 construction pilings were driven for the support of this centering and for the industrial track mentioned above. The contractor purchased a small portable sawmill and as these construction pilings were removed, they were sawed into lumber of such dimensions as the contractor deemed best fitted to his needs, and the waste material was given to those in need of fuel.

EMPLOYMENT OF LABOR

The average number of men employed on the work was about 50. Of these, about 40 were permanent residents of Richmond and probably would have remained idle if this work had not been done. Of the actual cost of the bridge, almost 40 per cent was paid out for labor. This does not include the men working at the gravel plant, those working on the piling, and other labor costs which were included in material furnished. I believe it would be agreed that at least 50 per cent of the total cost was expended for local labor.

COST

The contract price for the construction of the bridge was $198,845. It was found that one of the footings could be slightly raised without damage to the work. This decreased the contract price. It was also found necessary during the progress of the work to make some changes in the plans which resulted in extra costs. The most expensive of these was the

enlargement and deepening of the footing for the pier at the west end of the main arches. This was due to an irregularity in the face of the rock at the south end of the excavation. At the completion of the work, we were informed by the Traction Company that they would not build a track across the bridge at this time. It was then necessary to have the depression which had been left for the car track filled. This was filled with washed sand and covered by an 8-inch slab of concrete.

The detail cost of the entire structure was as follows:

Paid Contractor on Contract (lump sum)	$198,765.00
Paid Contractor on Contract (extras)	17,695.57
Attorney Fees	2,000.00
Engineering Costs	2,100.00
Indiana State Highway Commission (assistance and inspection)	2,978.21
Printing Bonds	264.00
Miscellaneous	267.22
Total	$224,070.00

The bonds for the cost of the structure bear interest at the rate of 4 per cent and are so arranged that they will all be paid in fourteen and one-half years.

This was our first experience with state inspection on county work and I would like to say that there was no trouble of any kind and that we were very much pleased with this arrangement.

WAGES FOR VARIOUS CLASSES OF COUNTY HIGHWAY EMPLOYEES

By A. C. Gengelbach, Perry County Highway Superintendent

The amount of wages paid for road labor has always been a source of criticism by the taxpayers. It presents a more difficult problem at present with so many men unemployed. Some taxpayers feel that one of the most necessary means of tax reduction is wage cutting. This may be justifiable in many cases, but the more important factor is the securing of competent workmen who will properly handle and care for the equipment and fulfill their duties in a workmanlike manner.

Our wage schedule varies for different classes of employees. Those who do general maintenance work, such as shoveling earth, loading scrapers, cutting brush, cleaning right of way, placing culverts, and doing other work of that kind, receive 20 cents per hour. Experienced road men capable of doing repair work receive 25 cents an hour. Truck drivers, tractor drivers, grader operators, stone-crusher feeders, drillers, and blasters receive 30 cents an hour.